THE UNIVERSITY OF BRITISH COLUMBIA

THE FABRICATION OF PRESSURE VESSEL NOZZLES BY ESC

Final Report: DSS Contract #OSU81-00149

By

A. Mitchell

DEPARTMENT OF METALLURGICAL ENGINEERING

MICROMEDIA

44 pp

VANCOUVER, BRITISH COLUMBIA • CANADA

THE FABRICATION OF PRESSURE VESSEL NOZZLES

Final Report

by

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MICROMEDIA

1 INTRODUCTION

The attachment of nozzles to 2¼ Cr/Mo pressure vessels is presently carried out in the majority of cases by manual metal arc welding. Thick, heavy nozzles are usually set through the shell and welded from both sides, the root run of the first side being gouged to sound metal before welding the second side. The filler metal is normally 2¼ Cr/Mo. Under existing ASME Codes (Sections III & VIII Div. 1 & 2): European Codes (German Unfired Pressure Vessel Code 19; BS5500, BS1113, BS2633) and the Pressure Vessels Quality Assurance Board Manual of Procedures 1980) there is no welding technique specified, for shell course construction, ring assembly, nozzle or head attachment. The Japanese Pressure Vessel Construction Code is likewise based only on test requirements not method. Accordingly various manufacturers have used submerged arc welding for nozzle attachment (e.g. Japan Steel Works, Kobe Steel Corp.) and TIG welding for the first attachment weld run (NEI; Jenkin Co. Ltd.). Similarly, various welding techniques have been employed for the vessel seam welds including electroslag welding, which has been used in 2¼ Cr/Mo vessels presently in service[1].

The nozzle attachment technique presently used has several disadvantages:

- set-up is time consuming
- weld procedure involves multipass welds with interpass inspection
- nozzle must be obtained from a forging supplier to the appropriate size and specification.
- nozzle attachment is an in-house fabrication procedure.

It also has advantages:

- the techniques for welding and testing are established and qualified.
- the method can be used equally well for large and small nozzles.
- the post-weld heat-treatment procedures are well established for 2¼ Cr/Mo[2-6].

The electroslag casting technique has been used for some years in the Soviet Union for nozzle manufacture and attachment. The technique is apparently well-established and vessels containing such structures have been supplied to users in both Europe and North America. The techniques used are surveyed in the background to this work[7] and are detailed by Inshcheneri et al[8]. In this latter report, nozzles are reported with deliberate composition gradients to facilitate attachment welds.

The pressure vessel construction codes do not specify nozzle manufacturing techniques and qualify the nozzle on properties alone. For this reason, there is no qualification barrier to using a cast material in nozzles, providing that a suitable test technique can be devised. Whether or not this point has proved a difficulty in the acceptance of Soviet pressure vessels is not yet resolved; nor are details of the Soviet qualification technique available, beyond the use of ultrasonics as the main NDT tool. This latter is in contrast to Western technology where radiation inspection is normally the main NDT tool on highly stressed vessels such as nuclear containment vessels.

From previous studies on electroslag-cast components and on electroslag welding it is clear that any component made by these techniques would have to be fully heat-treated in order to meet the property specifications in either high or low tensile strength classes of 2¼ Cr/Mo vessels. The implication of this, for almost all manufacturers is that either an elaborate local heat treatment technique would have to be devised, or else the nozzle attachment would have to take place at the stage of separately heat-treatable shell courses or heads. The precedent for both of these routes is established, with the local heat treatment of electroslag welds in shipbuilding (Mitsubishi Heavy Industries Corp.) and the one piece forging of heads and shell rings containing nozzles (Japan Steel Works). The intention of these applications is precisely that of electroslag-cast nozzle fabrication, although the techniques are very dissimilar; namely, the simplification of vessel construction.

The bases for the present investigation were, therefore:

- : an absence of code barriers to the electroslag assembly of nozzles.
- : the precedent of Soviet applications.
- : the possibility that vessel fabrication could be simplified by the technique.
- : absence of any in-service problems associated with conventional weld assemblies.

- : freedom from supply problems created by forged nozzle manufacture.

The programme was carried out as described below with the following objectives:

1.1 To examine potential methods for attaching nozzles by electroslag casting.

1.2 To verify the properties of the electroslag cast structure.

1.3 To extrapolate the most desirable technique to an industrial situation and assess the potential advantages over the MMA or SAW techniques.

2 EXPERIMENTAL

2.1 Development of the Casting Technique

Previous work on ESC nozzle casting showed that there are several potentially-viable techniques. The nozzle may be cast by melting an electrode into a through-hole in the plate and thereby making a weld through the plate thickness, terminating in a nozzle casting (Figure 1 (b)). A second technique would be to cast the nozzle directly onto the plate surface (Figure 1 (a)) with adequate plate preheating to assure complete fusion between nozzle and plate. The third technique (Figure 1 (c)) is a compromise between the two, the plate being prepared with a recess into which the nozzle is cast, again at a sufficient plate pre-heat to assure complete fusion.

The experimental work carried out investigated each of these techniques, using a water-cooled aluminum casting mold of the 900 lb Type H nozzle configuration (i.e. a straight nozzle 8" high and 5" O.D., 1½" wall thickness), for welded pipe attachment.

Initial investigations into casting the nozzle with small plate electrodes arranged around a withdrawn water-cooled copper mandrel showed that although it is possible to make the hollow nozzle configuration directly, it is a complex operation and not cost-competitive with boring a solid cast nozzle in this size range. (Examination of an ESC nozzle manufactured in the Soviet Union revealed

that this 150 mm dia. nozzle had also been manufactured as a solid and subsequently drilled). For this reason we have concentrated subsequent work on the casting of solid nozzles for subsequent drilling of the centre hole.

The results of the investigations show that there are well-defined problems associated with each of the techniques shown ir Figure 1. The system described by 1 (b), is, mechanically, the simplest. A hole is made in the plate by torch cutting, and with no preparation, the mold is placed on top of the plate and the ESC nozzle cast into it. For the size of nozzle under study, we used the following ESC conditions:

Slag (wt%) CaF_2 55 CaO 15 Al_2O_3 15 Re_2O_3 15
(3.8 Kg).

Electrical: 35-37V 3.5 kA

Melt-rate: 1.5 Kg/min.

These conditions produced an adequate fusion zone within the plate and a good macrostructure in the cast portion. The major drawback of the technique is that weld attachment region of the casting is a fully constrained weld and has a marked tendency to form shrinkage cracks in the centre region. Our investigations showed that with close attention to the hot-top cycle of the process this effect could be minimized to the point that the cracking is confined to the region removed by the subsequent hole boring, but even in an automated system this cracking would remain a potential hazard. However, to the

extent that this technique does not require plate pre-heating it is the simplest technique of nozzle attachment.

The second potential technique (Figure 1 (a)) required strong plate pre-heating to achieve fusion. Although this pre-heating does not pose any insurmountable problems it is mechanically complex since the pre-heating is difficult to arrange with the mold in position. After a number of trials using both electrical and gas pre-heating it was concluded that this technique does not present a viable industrial route. The alternative pre-heating system, namely that of fusing slag in the mold using a non-consumable electrode, was therefore investigated. The system is shown in Figure 2. The operational sequence is as follows:

1) the water cooled mold is positioned over the plate.
2) a graphite electrode in a water-cooled copper holder is attached to the end of the working electrode and positioned in the mold.
3) the slag is fused outside the assembly in a graphite crucible and added to the mold as a liquid.
4) the system is heated by the graphite electrode for approximately 5 min. at a high power input (6 kA).
5) the graphite electrode is rapidly removed and the working electrode rapidly lowered into the slag.
6) power is re-established at a high level (6 kA) until the required meltrate (1.5 Kg/min) is obtained.
7) the casting then proceeds as in the previous case.

The principal difficulty associated with this technique is one of minimizing carbon pick-up during the slag fusion period. We found that the adequate heating period of approximately 5 min established a steady-state temperature gradient below the weld region (by implanted thermocouples). For this pre-heating period, the use of even acid slags (65 CaF_2 + 30 Al_2O_3 + 5 SiO_2) did not prevent the transfer of carbon from the electrode to the slag. When the 2¼ Cr/Mo electrode was melted into the assembly, the initial metal absorbed this carbon content, to give a small region in the weld centre of high carbon content. Although drilling of the nozzle removes this contaminated region, it is desirable to eliminate it and in consequence effort was concentrated on developing a technique which would remove the contamination by carbon.

The first technique used was to attempt to remove the carbon from the slag by oxidation. In this method we analysed the slag for carbon at the end of the pre-heating cycle and found it to contain 0.1 to 0.2 w/o carbon. Based on a mass balance and equilibrium calculation, this content was found to be equivalent to a 50 g addition of FeO in the reaction:

$$(C) + FeO\ (\ell) = Fe\ (\ell) + CO\ (g).$$

Accordingly the slag was treated with 50 g FeO powder in stage (5) above, between removing the graphite electrode and inserting the working electrode. The success of this technique was evaluated by analysing the weld centre region for carbon. It appears that although

carbon can be eliminated by this reaction, because the carbon content of the slag is very sensitive to the electrode immersion and temperature it is highly non-reproducible. In consequence the precise addition of FeO required is not predictable and we risk adding too little (in which case there is carbon pick-up) or too much (in which case there is silicon depletion in the initial alloy solidified). With rapid on-line slag carbon analysis the technique might be viable, but is probably not feasible for most vessel assembly shops.

In an attempt to reduce the level of carbon pick-up, but still using a graphite pre-heating electrode, we investigated the extended arc plasma technique. In this method, a small flow of argon is fed down a central hole (4 mm ϕ) in the graphite electrode. The resulting mixture of slag vapour and argon gas on the electrode tip is highly ionizable and gives a low resistance arc plasma. As a result, the electrode may be withdrawn several centimeters above the liquid slag surface, maintaining the heat input but eliminating physical contact between the hot graphite and the slag. The technique worked as predicted, but analysis of the weld centre revealed no appreciable decrease in carbon pick-up, or any increase in its reproducibility. The extended arc plasma therefore was rejected as a solution to this problem.

The most promising way to eliminate the problem of carbon pick-up appears to be the use of a molybdenum-tipped electrode. The construction of this electrode is as follows. A 38 mm ϕ molybdenum

rod, 100 mm long is attached to a 50 mm ϕ steel bar by means of a threaded joint. The steel bar is used in the quick-fit connection developed for the graphite electrode. Liquid slag, fused externally in a graphite crucible is added to the mold and power applied at 160 kW by means of the molybdenum electrode. At the same time, 50 g FeO is added to the slag to remove all carbon. Any excess FeO reacts with the molybdenum electrode to produce MoO_2 which coates the electrode surface. After 5 min the change to the working electrode is made and the electroslag casting initiated.

Using this method we find that the carbon pick-up is reduced to zero, and that the small amount of reaction between FeO and the molybdenum electrode leads only to a slight increase in the centre region Mo content from 1 w/o to 1.1 w/o, in the worst case observed. A careful re-examination of composition gradients in the Soviet ESC nozzle obtained suggests that this may also have been the technique used in that case also. The technique is complicated by the need to use an argon cover over the system to prevent excessive air oxidation of the molybdenum. Attempts to prevent this oxidation by applying coatings have so far proved unsuccessful. Also the molybdenum electrode, although probably re-usable for at least twenty melts, is costly and not simple to construct as careful machining is required to ensure good electrical contact at the molybdenum-steel interface. Failure to observe this latter precaution results in arc damage and rapid premature failure of the joint.

Examples of the assembly and ESC nozzles are shown in Figures 3-8.

2.2 ESC 2¼ Cr/Mo Properties

The starting material for the programme was commercial electric furnace/vacuum degassed 2¼ Cr/Mo plate (7½" thick) obtained from the Lukens Steel Co., Coatesville, PA. It was in the annealed condition and had the following composition (wt%).

TABLE I

C	.13	Mo	1.00
Mn	.36	Si	0.08
P	.010	Al	0.022
S	.010	Sn	0.004
Cu	.12	As	0.011
Ni	.10		
Cr	2.28		

It is material conventionally supplied to manufacturers of pressure vessels in material of the type A387-22.

Electrode material for electroslag remelting was prepared by cutting slices from the plates to give electrode sections falling within a 3" dia. circle, the required geometry for the selected nozzle. These pieces were then fabricated into electrodes by TIG welding.

All electroslag melting of this material was carried out using the slag:

CaF_2 55 CaO 15 Al_2O_3 15 Re_2O_3 15

which produces strong desulphurization but does not otherwise change the steel composition. Chemical analysis of the ESC material showed sulphur levels between 0.001 and 0.0015 with other elements as shown in Table I.

Samples were cut from an ESC nozzle as shown in Figure 9 for testing and were heat-treated as follows:

Condition 'A' Austenitize 2H @ 920°C, water quench
Temper 6H @ 625°C, air cool.

Condition 'B' Austenitize 2H 2 920°C, water quench
Temper 6H @ 665°C, air cool.

The samples were tested with the following results:

TABLE II

Condition 'A'

	YS(kSi)	UTS(kSi)	E%	RA%
LP	85.4	101.4	28	75
LT	84.4	100.0	24	74
LC	86.0	100.6	32	75
STP	85.5	101.2	26	75
STT	86.0	100.1	28	73
STC	85.4	101.4	28	75

	CVN (ft.lb.)					
	20°C	0°C	-40°C	-60°C	-70°C	-80°C
LP	72	75	50	41	22	5
LT	78	72	70	56	28	15
LC	112	136	117	118	4	4
STP	70	74	61	42	18	10
STT	69	68	60	49	15	5
STC	112	103	97	104	11	6

TABLE II (cont'd)

Condition 'B'

	YS(kSi)	UTS(kSi)	E%	RA%
LP	96	115	22	74
LT	98	112	22.5	70
LC	100	113.8	30.5	75
STP	94	110	21.0	74
STT	100	112	20.0	68
STC	98	112	21.2	74

CVN (ft.lb.)

	20°C	0°C	-40°C	-60°C	-70°C	-80°C
LP	78	62	58	40	18	5
LT	64	66	50	41	22	5
LC	118	127	86	47	6	4
STP	74	72	54	43	21	5
STT	68	70	50	38	20	5
STC	109	103	90	34	4	4

Spec. :		
A38/-22	YS(kSi)	75-100 (95 typ.)
Class 2	UTS(kSi)	45 min (80 typ.)
	%E	25 min (25 typ.)
	%RA	40 min (70 typ.)
	CVN	40 ft.lb. @ 10°C (40 ft.lb. @ -40°C typ.)

We conclude from this survey of properties that the ESC material has properties well in excess of the code requirements for this alloy. It is not clear why the fracture properties should be superior, but we believe that this may be connected with the very low levels of sulphur in the casting. However, since a slag with rare-earths was used in the electroslag process there is also the possibility that sufficient rare earth equilibrated into the metal to reduce

the effects of P, Bi, As and Sn on the fracture values, thus giving a low value for the Bruscato factor. However, investigations of the fracture surface with the available electron optics tools (SEM and STEM) failed to reveal any definitive evidence on this suggestion.

Samples from each of the regions shown in Figure 9 were subjected to tests for temper embrittlement. Of the three main recommended step-cooling embrittling treatments (G.E., C.F. Braun & Co. and Standard Oil of California) it was decided to use the G.E. scheme of time/temperature for embrittling, for Condition 'B' heat treated material:

TABLE III

Temp.	Time at Temp.	Cooling Rate from Temp.
595°C	60 min.	0.1°C/min.
540	900	0.1
525	1440	0.1
495	3600	0.05
470	7500	0.5
315	-	air cool

Following this scheme of embrittlement, the material was impact tested and the CVN values obtained for the various positions in the assembly, as shown in Table IV:

TABLE IV

	20°C	0°C	-40°C	-60°C
LP	61	49	44	36
LT	55	52	41	32
LC	104	94	56	36
STP	55	51	44	30
STT	50	51	40	33
STC	92	84	48	32

As expected, the step cooling treatment produced a substantial loss in toughness in all parts of the assembly, which would be predicted from the literature. However, there is a slightly lower reduction of toughness at the higher temperatures for the electroslag portion of the assembly, samples LC and STC. We believe that this may be supporting evidence for the influence of the resulting slag on residual element behaviour, since the embrittlement extent is closely linked with these elements. In view of the nature of the CVN test, however, it would be necessary to conduct more extensive fracture investigations to confirm this hypothesis. From the test results one can nonetheless conclude that the electroslag cast assembly behaves in a similar manner to conventionally prepared nozzle assemblies in respect of temper embrittlement.

From the above results we suggest that the ESC nozzle does not present any fundamental problems in passing code qualification tests for the component requirements.

3 INDUSTRIAL USE OF THE TECHNIQUE

3.1 Assembly Problems

Requests for an industrial critique of the method by means of a circular and also individual contacts provided a variety of points at issue concerning the potential industrial use of the techniques. The major one centres around the question of the heat treatment necessary to produce adequate properties in the cast part. It appears from this work, and from previous ESC studies on similar alloys, that a full heat treatment, i.e. quench and temper treatment will be necessary to assure the impact properties of the nozzle assembly. As pointed out by AMCA International (Appendix I), this would imply either a challenging local heat treatment technique, or facilities for treating the shell course sections after nozzle assembly but before shell seam welding. From the viewpoint of the shop fabrication route this latter would mean additional heat-treatment, quench-tank and crane facilities for all Canadian fabricators - although many off-shore fabricators presently heat treat large vessel ring forgings in piece weights up to 400 tonnes. For Canadian fabricators wishing to use the ESC technique therefore the choices are:

3.1.1 Install new heat treating facilities for large vessel treatment

3.1.2 Devise local normalize/quench/temper equipment for the nozzle region.

3.1.3 Use the process at an early stage in ring fabrication when the piece size is small enough for existing heat-

3.1.3 (cont'd)

treatment facilities.

Of the above choices, it would appear that 3.1.3 is best suited to present Canadian conditions although 3.1.1 is used by competitive fabricators off-shore.

The second major question of nozzle assembly is that of machining operations to be carried out on the nozzle after heat-treatment. For the nozzles we have considered these would be:

- : central hole machining
- : hand cleaning (by grinding) of the vessel inner surface
- : facing and drilling the flange assembly if bolted connections are required instead of welding

All of these operations would be carried out before shell assembly, but nevertheless would entail machining work on a large ring section. These operations are probably feasible from a technical standpoint in all Canadian vessel fabrication shops. They would, however, add substantially to the cost of the operation. We do not at present see a feasible way to avoid final machining on a nozzle made by this method.

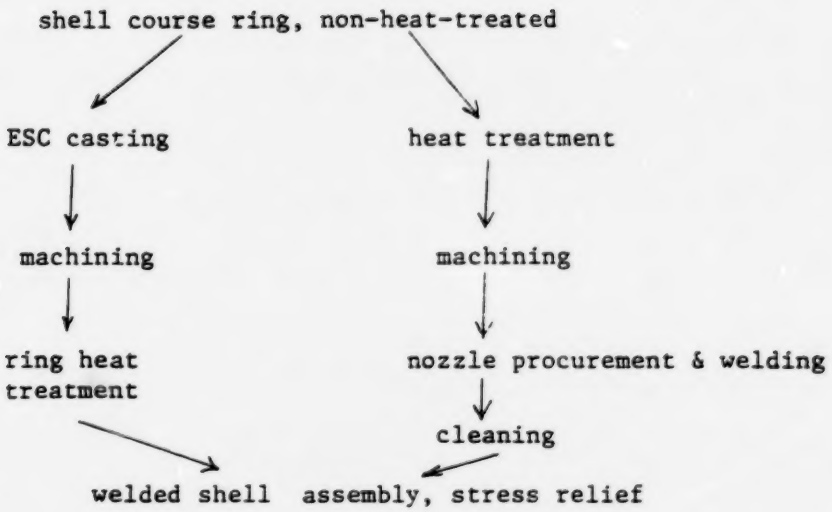
The third point concerns the question of feasible dimensions. The height of the nozzle is not a critical factor and could be made extremely long if required e.g. up to 1000 mm. The maximum feasible diameter, however, is a function of what power source could reasonably

be connected to the casting system. Although there is no "in principle" limit to the power source size, it is probably not reasonable to anticipate availability of power in excess of 500 kVA 60 Hz single-phase for the typical fabrication shop. This would lead to a maximum available power of approximately 450 kW in the nozzle casting furnace. An extrapolated heat balance, based on our present results for 200 mm dia. nozzles leads to the conclusion that this power supply would be adequate for nozzles up to 380 mm dia., this then representing the maximum feasible size.

The above discussion and conclusions lead to a position in which the ESC nozzle technique is probably best suited to vessels with a multiplicity of small, similar-sized nozzle attachments. The advantages of ESC in rapid fabrication would then outweigh its disadvantages in respect of machining time.

3.2 Economic Considerations

We have taken as our base the fabrication of a 200 mm dia. welded-connection nozzle, assembled before the shell course ring heat treatment. The cost of heat treatment is therefore not included, and the comparison with conventional techniques should be drawn:



The following economic data are developed, based on the assembly of 200 nozzles/yr:

	1983 $/nozzle
· Equipment, $60,000 amortized at 20%/yr	60.00
Materials & power	10.00
Manpower (5 man hrs. @ $15)	75.00
Machining (10 hr. @ $30/hr.)	300.00
	$445.00

Since the heat treatment cost is common to both techniques this value is to be compared with the cost of:

(Nozzle body + welding + cleaning)

in the conventional route. Although a precise comparison depends on the shell size and fabricators techniques, we believe that the ESC cost is comparable to conventional even in the unfavourable case chosen. For an assembly of a highly repetitive nature e.g. a heat

exchanger body, the ESC cost would reduce very significantly as both equipment amortization and machining time would be reduced. We conclude, therefore, that the ESC technique offers economic advantages over the conventional route, particularly in the case of repetitive nozzle assembly.

4 CONCLUSIONS

4.1 Electroslag casting of nozzles in 2¼ Cr/Mo steel gives adequate mechanical properties after a normalize/quench/temper heat treatment. There are no unexpected effects of step-cooling on temper embrittlement.

4.2 There are no code qualification barriers to the process which appears to be permitted by present codes in Canada, U.S.A., Europe and Japan.

4.3 The process is cost-competitive with the conventional route even at low production rates, in nozzle sizes up to approximately 380 mm dia.: it becomes of economic advantage of the case of repetitive, multiple attachement of small nozzle sizes.

5 RECOMMENDATIONS

5.1 An accurate cost comparison be carried out for a specific case where ESC might be competitive, by a vessel manufacturer.

5.2 If 5.1 is favourable, a demonstration nozzle be prepared for in-service testing alongside a conventional nozzle.

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APPENDIX I

November 30, 1982

Dr. J.T. McGrath
Head, Welding Section
PMRL, EMR
568 Booth Street
Ottawa, Ontario

Dear Jim:

My colleagues and I have reviewed the progress report on "The Fabrication of Pressure Vessel Nozzles by Electroslag Casting", and our comments are as follows:

A. The first question concerns the cost effectiveness and/or unique technical advantages of this approach as compared to conventional nozzle welding. Presumably this aspect was addressed in the original proposal, and perhaps economic aspects should be reconsidered taking into account the heat treatment costs.

B. The mechanical properties have been examined in the quenched and tempered condition. It would be preferable to include a stress relief and step cooling treatment so that no uncertainty remains, at least from the point of view of mechanical properties after code or common design stipulated heat treatments.

C. Since the nozzle could be attached to fairly heavy wall vessels, there would obviously be a need for in situ heat treatment. From a practical standpoint, a normalizing treatment would be straight forward and preferable to quenching and tempering since either a gas heater or resistance heater with insulation could be adopted for various nozzle sizes.

   This in turn, however, points to the need for studying the cast metal (and heat affected zone) properties in the normalized and stress relieved (and step cooled) condition.

.../2

D. If it is found that the normalizing treatment does not give adequate properties, then in situ quench and temper is the only option left. This would rule out resistance heaters for austenitizing because of the time involved in removing heaters and insulation. Instead, hardware involving gas heaters and appropriate water-air spray would have to be developed.

In this context, a modular approach to equipment design would be desirable, and it would be beneficial to standardize nozzle sizes.

No particular size limitation is seen for local normalizing treatment. However, for quenching and tempering, effective cooling of I.D. surface of small diameter nozzles would be a challenge. Development work would need to be done in any case to assure that correct austenitizing temperature and soaking times are achieved at all locations.

I trust these comments are of help in planning further work, and before closing, I would like to apologize again for the delay in responding.

Best regards,

L. Malik

LM:pl

cc: D.E.H. Reynolds

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Celebrating our 75th Anniversary

September 14th, 1982

Dr. J.T. McGrath,
PMRL,
568 Booth Street,
Ottawa, Ontario,
K1A 0G1

Dear Jim:

Thank you for the copy of Alec Mitchell's report on ESC fabrication of pressure vessel nozzles. The mechanical properties of the materials look excellent, especially in the cast metal. The HAZ appears to be at least as good as the parent metal as well, which is something I, for one, did not expect.

Only two comments at the present time - 1) are these nozzles to be cast in a separate sub-section, or on a large vessel during fabrication? and 2) perhaps forged or pressed end fittings would provide starting recesses without the complication of machining. My concern with putting nozzles on semi-finished vessels is one of access and safety. The fittings I have in mind for startup can be pressed as hollow hemispheres about 150-200 mm dia. and with a wall thickness of 15-50 mm.

Yours sincerely,

B.M. Patchett,
NOVA Professor of Welding Engineering

BMP/mf

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September 7, 1982

Energy, Mines & Resources Canada
Research & Technology
Canada Centre for Mineral and
Energy Technology
555 Booth Street
Ottawa, Ontario K1A 0G1

ATTENTION: MR. J. T. MCGRATH

Dear Mr. McGrath:

Thank you for your letter of August 17 and the report of Prof. Mitchell's concerning nozzle casting into a pressure vessel wall. It certainly is a novel idea and appears to have great potential.

As you know, we are completing some narrow gap welding procedures which have many applications and one of these looks like it might overcome the conventional welding difficulties with the shell and nozzle joint.

In any event, we hope Prof. Mitchell is successful in his unusual challenge.

Yours very truly,

WELD PROCESS INTERNATIONAL LIMITED

John G. Church, P. Eng.
Welding Engineering Dept.

JGC:plv

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Directeur
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8221-1

August 31, 1982

Mr. J.T. McGrath
Canada Centre for Mineral
and Energy Technology
555 Booth Street
Ottawa, Ontario K1A OG1

Dear Mr. McGrath:

My colleagues and I have read Prof. A. Mitchell's progress report entitled "The Fabrication of Pressure Vessel Nozzles by Electro Slag Casting".

This is an excellent report which appears to confirm the possibility of technological alternatives for the installation of nozzles on pressure vessels, within established codes. We wonder what is the economic justification to modify existing industrial practices and this is one aspect you may wish to look into.

One of our reviewers commented that Prof. Mitchell could have used perhaps SI units in his report.

Please let us know if there is any assistance we could render to you should you intend to proceed with this project.

Thank you for asking us to comment.

Sincerely yours,

George L. Bata

GLB:mr

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Attention Mr. J. T. McGrath

Dear Sirs:

Thank you for the copy of the progress report "The Fabrication of Pressure Vessel Nozzles by Electroslag Casting". We are familiar with the work being done by Dr. Mitchell and are following it with interest.

In the introduction on page 1, the statement is made "that the overwhelming majority of pressure vessel nozzles are intended for welded connections rather than bolted flanges". This is in fact contrary to our experience. We very seldom supply customers with nozzles with welded connections. This is not to say our customers could not change their piping design if there were significant benefits to be obtained. There are two points that should be made:

(1) If bolted connections are required, the difficult machining operation of facing and drilling the nozzle in position must be included in the cost analysis.

(2) If welded connections can be used the extra cost of fitting and welding in the field, usually about twice shop costs, must be considered.

We are hopeful that Dr. Mitchell's work will show that "Nozzle Casting" will be cost-effective and await further developments.

Yours truly,

VICTORIA MACHINERY DEPOT CO. LTD.

Eric L. Dyke
Chief Engineer

ELD/hh

CHEMA
2175 SHEPPARD AVENUE EAST - SUITE 110
WILLOWDALE, ONT. M2J 1W8 - (416) 491-2886

cc
Further Comments
re Electro
Slag
report

January 11, 1983

Jim McGarth

Mr. J. T. McGarth
Energy, Mines and Resources Canada
555 Booth Street
Ottawa, Ontario
K1A 0G1

Dear Mr. McGarth:

RE: File 420502 - AUGUST 17, 1982

We are enclosing the reply received from E. Friedrich & Associates Consulting Inc., regarding the Fabrication of Pressure Nozzles by Electro - Slac Casting.

Sincerely,

Olive Marshall
Enclosed

E. Friedrich & Associates Consulting Inc.

C.H.E.V.M.A.
2175 SHEPPARD AVENUE, EAST
SUITE 110
WILLOWDALE, ONTARIO
M2J 1W8

ATTENTION: OLIVE MARSHALL
EXECUTIVE ASSISTANT

DEAR MADAM,

THE FABRICATION OF PRESSURE NOZZLES BY ELECTRO - SLAC CASTING

THANK YOU FOR YOUR LETTER OF OCT. 25, 1982, ENCLOSING DR. MITCHELL'S PAPER ON THE ABOVE SUBJECT. WE HAVE REVIEWED THE MATTER, AND WOULD COMMENT AS FOLLOWS:

AS YOU ARE AWARE, ELECTRO - SLAC WELDING HAS BEEN USED FOR SOME LENGTH OF TIME, AND DR. MITCHELL IS ENDEAVOURING TO DO MUCH THE SAME THING WITH ASSURANCE OF BETTER CONTROLLED CONDITIONS. THE DIFFICULTIES PREVIOUSLY WERE:

1) DUE TO INABILITY TO CONTROL UNPREPARED SURFACES, A RESULTANT VARIANCE OF FUSION.

2) DUE TO LARGE ENERGY INPUT - SHRINKAGE CRACKS AND HIGH ENERGY COST.

3) HYDROGEN EVOLUTION OF THE UNDERSIDE OF THE WELD THROUGH MOISTURE DISASSOCIATION.

4) HIGH LABOUR INPUT FOR SETTING UP THE CONSTRAINING WALLS.

5) ALTHOUGH THE OPERATOR SKILL IS REDUCED, THE PERSON REQUIRED TO CONTROL SUCH A PROCESS, HAS TO BE OF A MUCH HIGHER CALIBER AND THEREFORE, COST.

6) SINCE E.S.W. WAS USED ON VERTICAL FILLED WELDS ONLY (THICK MATERIAL), THE PROBLEM OF MOVING THE WATER COOLED RETAINING WALLS UP THE PLATE, ALWAYS PRESENTED DIFFICULTIES.

7) SINCE WATER WAS USED FOR COOLING, EXTREME CARE WAS REQUIRED THAT IT DID NOT GET SCATTERED AROUND, AND INTO OR NEAR THE WELD AREA.

THE ABOVE WERE SOME OF THE MANY DIFFICULTIES ENCOUNTERED, AND THUS THE USE OF E.S.W. WAS RESTRICTED TO WHAT IT ACCOMPLISHED BEST, NAMELY WELDING OF VERY THICK PLATE, BUT EVEN NOW, IT IS NOT A COMMON PROCESS. DR. MITCHELL OBVIOUSLY HAS ENDEAVOURED TO CONTROL

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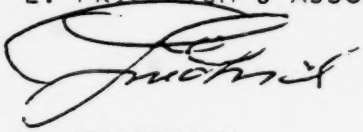
THE PROBLEMS, WITH REGARD TO SOME CONDITIONS OF ACTUAL WELDING, HOWEVER, THERE IS ALWAYS DOUBTS ON THE TRANSPOSITION OF TECHNIQUES FROM A LABORATORY TO A NORMAL SHOP FLOOR. FURTHER, THE DISCUSSION AND PRESENTATION DO NOT FURNISH SUFFICIENT DETAIL TO TOTALLY EVALUATE THE RESULTS. NOR DOES THE COMMENT ANSWER QUESTIONS RELATED TO PAST DIFFICULTIES. ON THE ECONOMIC EVALUATION, AGAIN, THERE IS INSUFFICIENT INFORMATION TO MAKE COMPARISONS OF THE PROPOSALS AGAINST, SAY, SHIELDED METAL ARC WELDING; OR EVEN SUBMERGED ARC.

SUMMARISING, IN GENERAL, IT IS NOT POSSIBLE TO FULLY APPRAISE THE VALUE OF THE WORK, FROM THE COMMENT IT IS OBVIOUS, MANY OF THE KNOWN, PAST PROBLEMS HAVE NOT BEEN RESOLVED. WE SUGGEST THAT THE PROCESS MAY HAVE VALUE IN SPECIFIC CASES OF WELDING, IT IS ALMOST CERTAIN THAT IS NOT A UNIVERSAL PANACEA FOR ATTACHMENT OF NOZZLES. THE ECONOMIC QUESTION REQUIRES TO BE ADDRESSED RELATIVE TO FABRICATION SHOP UTILIZATION; AS ALSO, INVESTIGATION OF RESULTS UNDER NORMAL CONDITIONS USING NORMAL LABOUR IN A FABRICATION SHOP, AS OPPOSED TO HIGH TECHNICAL LABORATORY CONTROL.

WE HOPE THE ABOVE COMMENT WILL HELP, AND SUGGEST DR. MITCHELL SHOULD BE ASKED FOR FURTHER COMMENT AS IT BECOMES AVAILABLE.

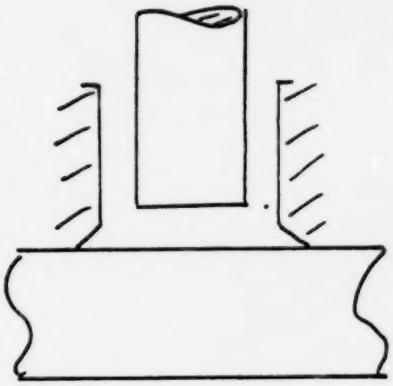
YOURS VERY TRULY,

E. FRIEDRICH & ASSOCIATES CONSULTING INC.

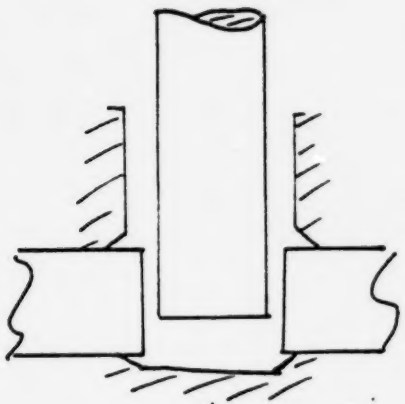


E. FRIEDRICH

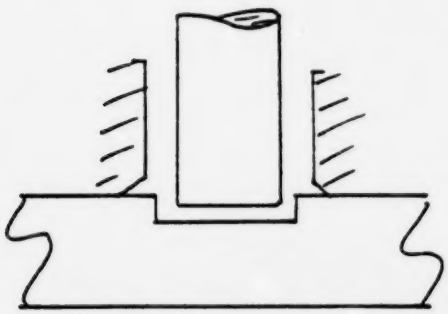
EF/RP



(a)



(b)



(c)

Fig 1

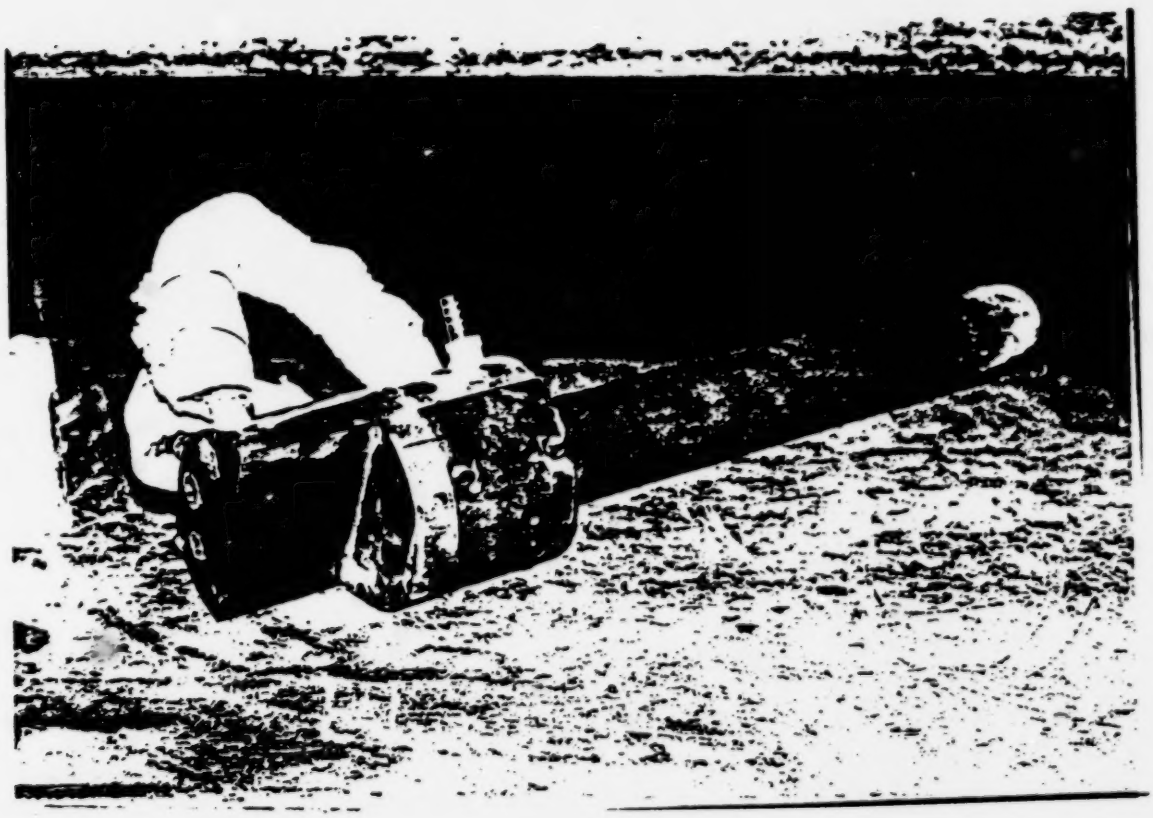


Figure 2(a): Non-consumable graphite electrode.

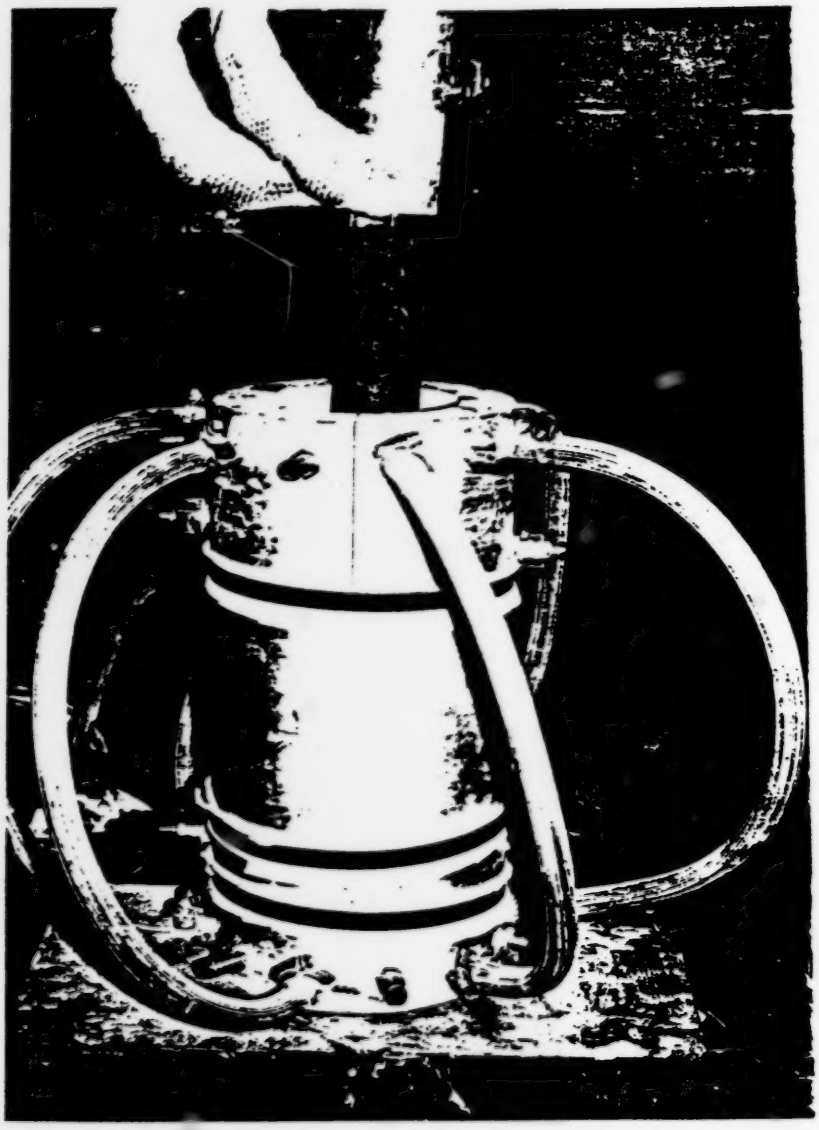


Figure 2(b): Graphite electrode in mold assembly.

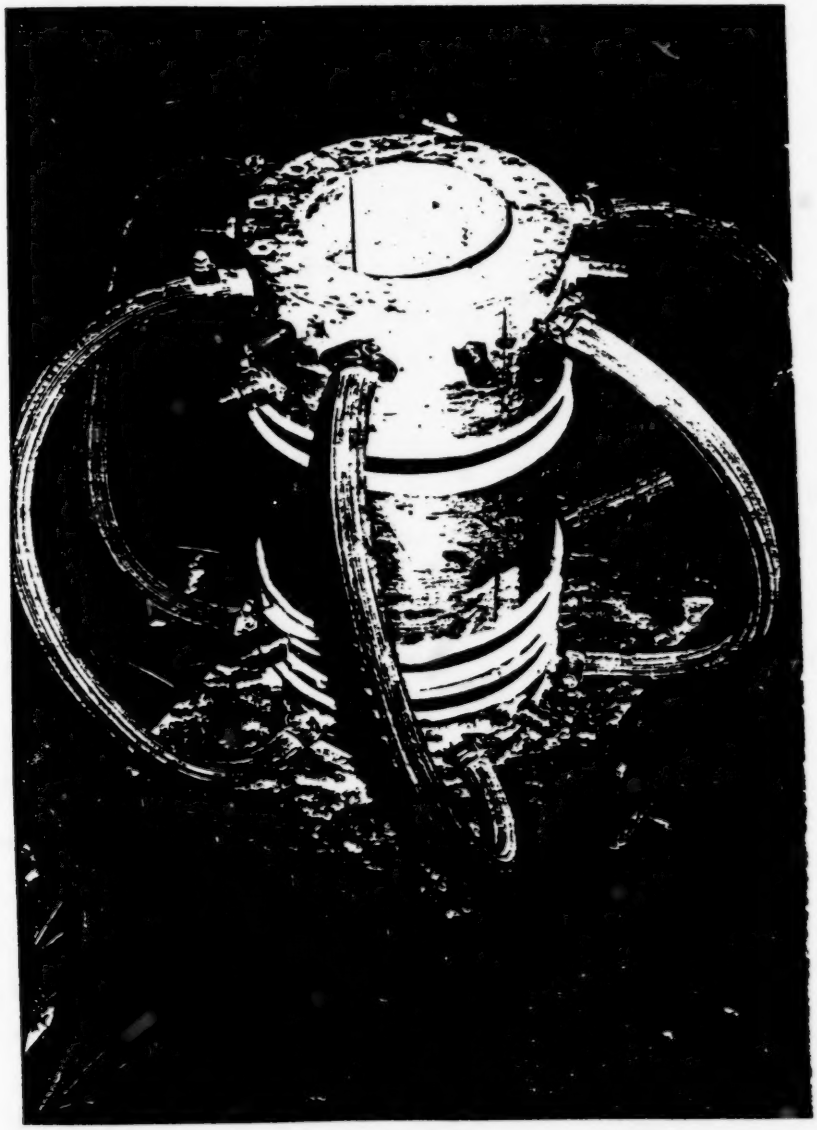


Figure 3: Mold assembly on plate.

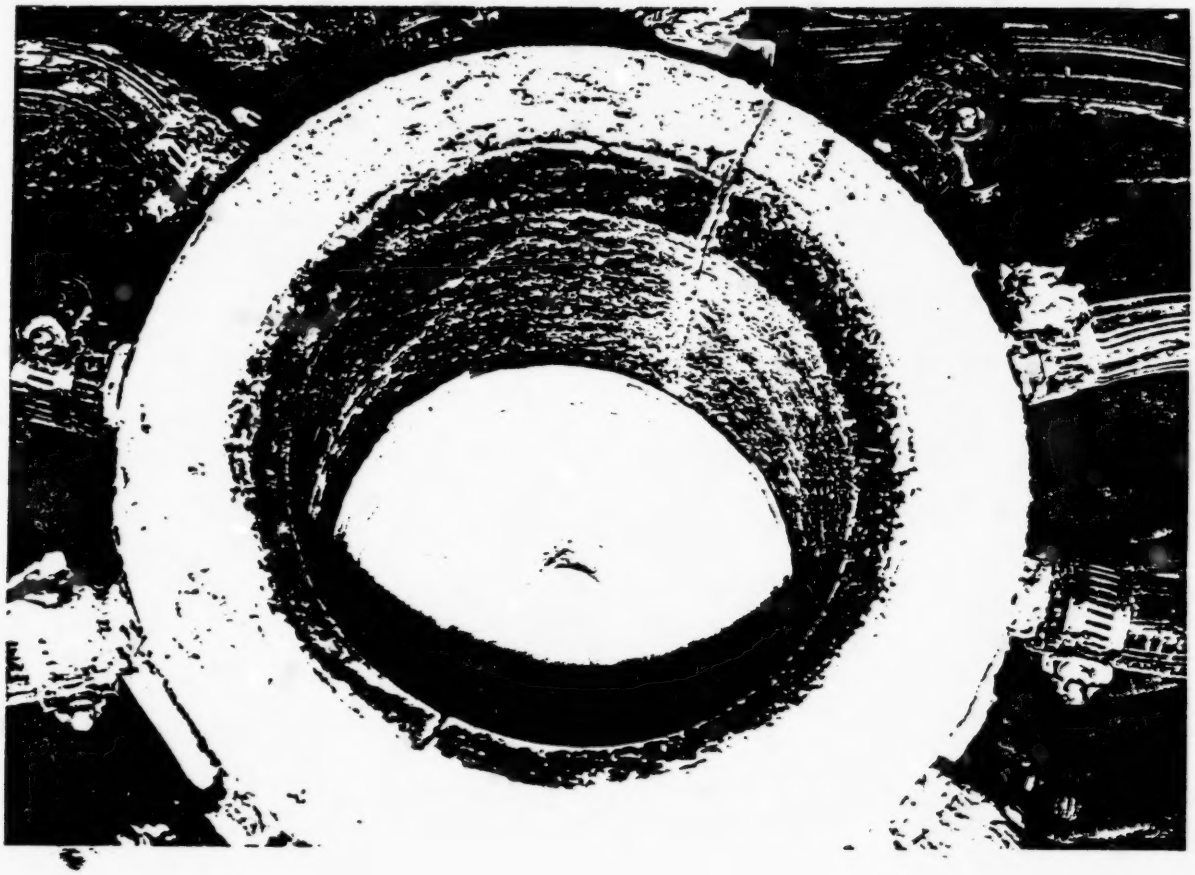


Figure 4: Slag after completion of casting.

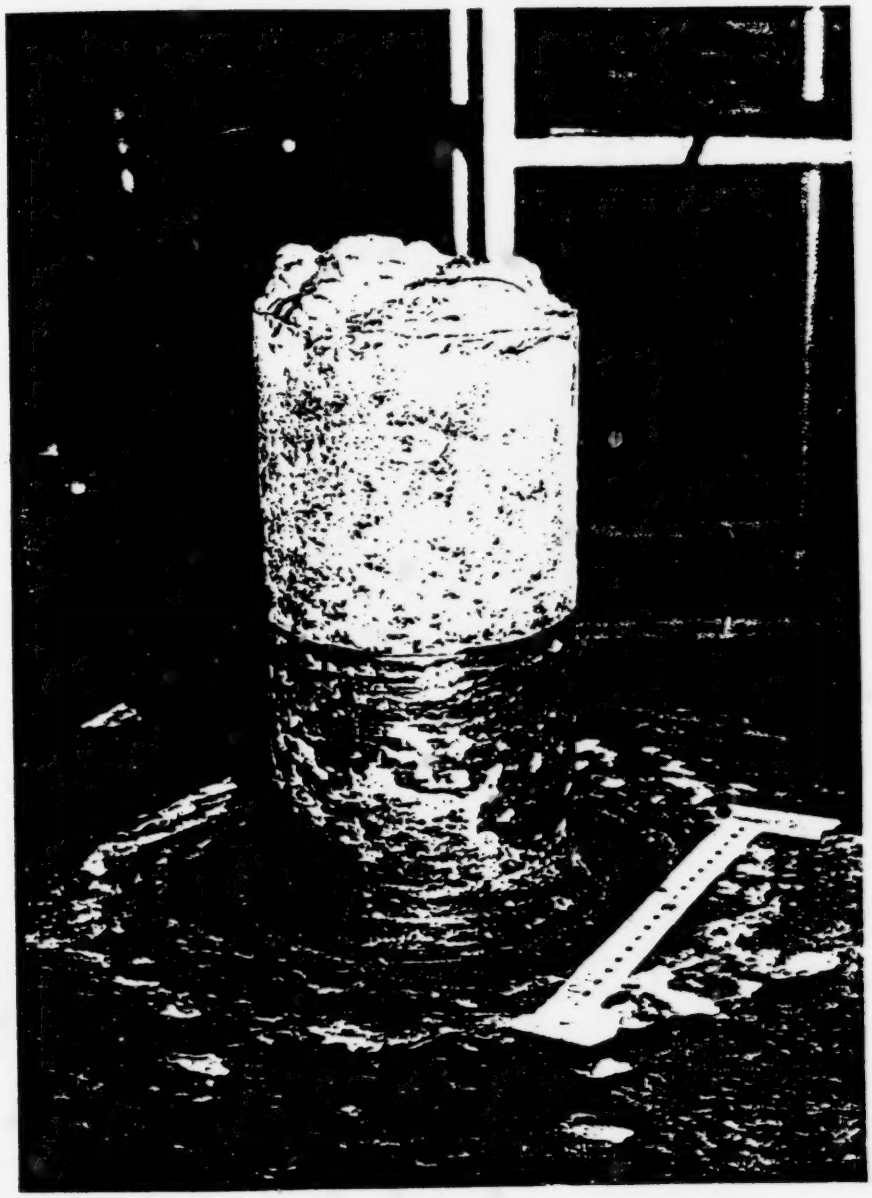


Figure 5: Completed nozzle casting with slag.

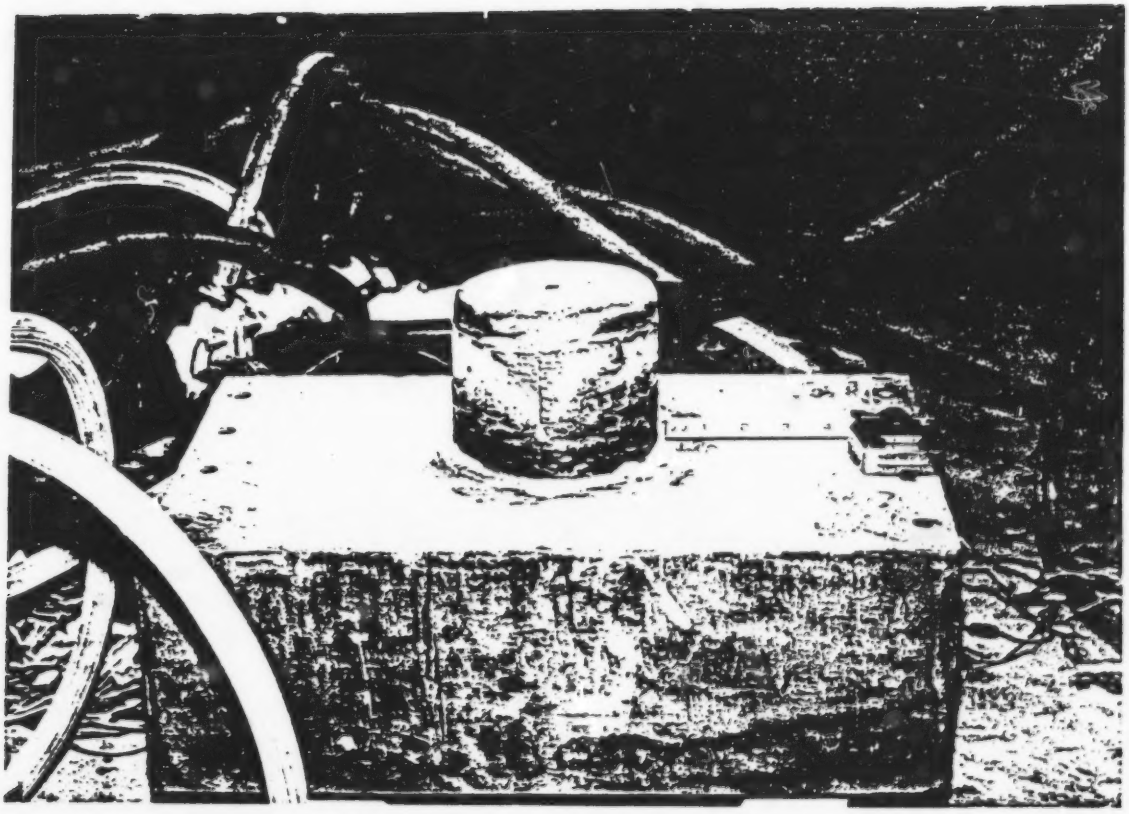


Figure 6: Nozzle casting.

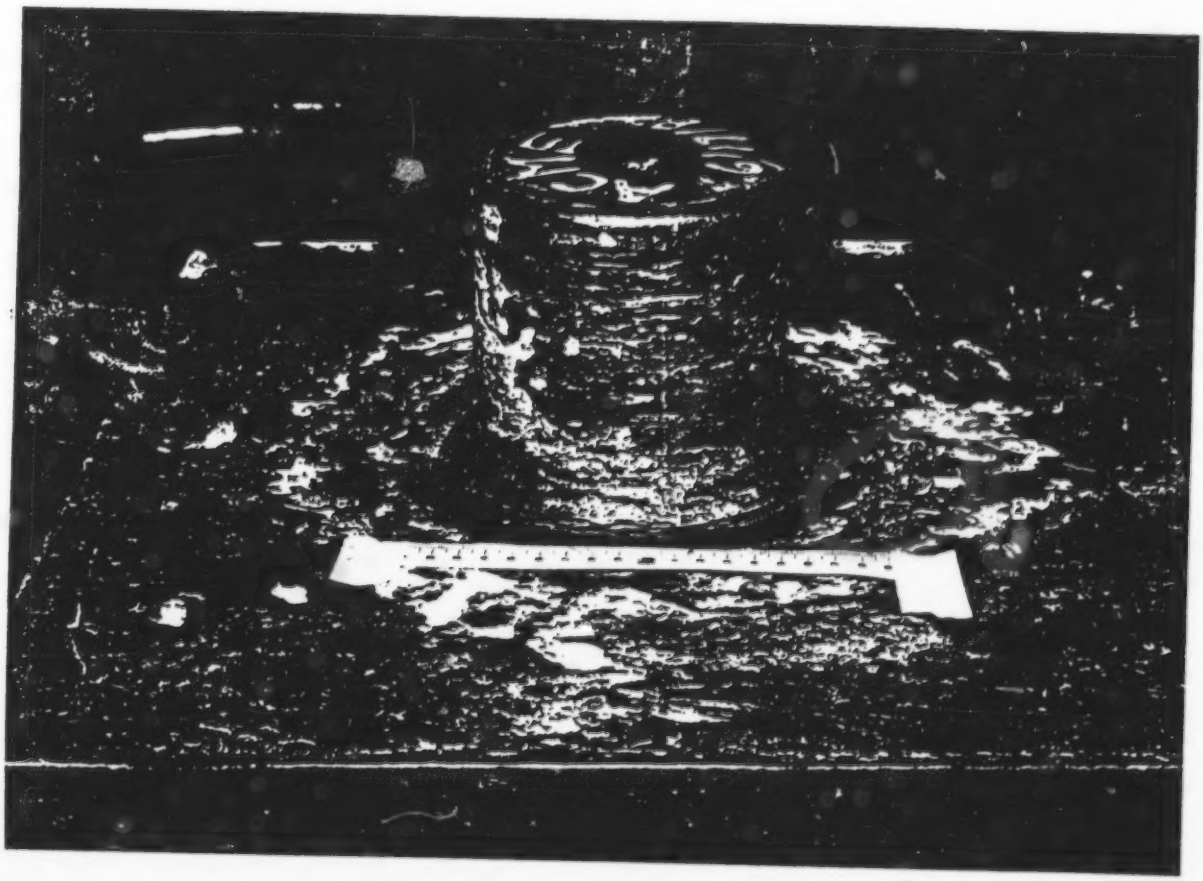


Figure 7: Nozzle casting.

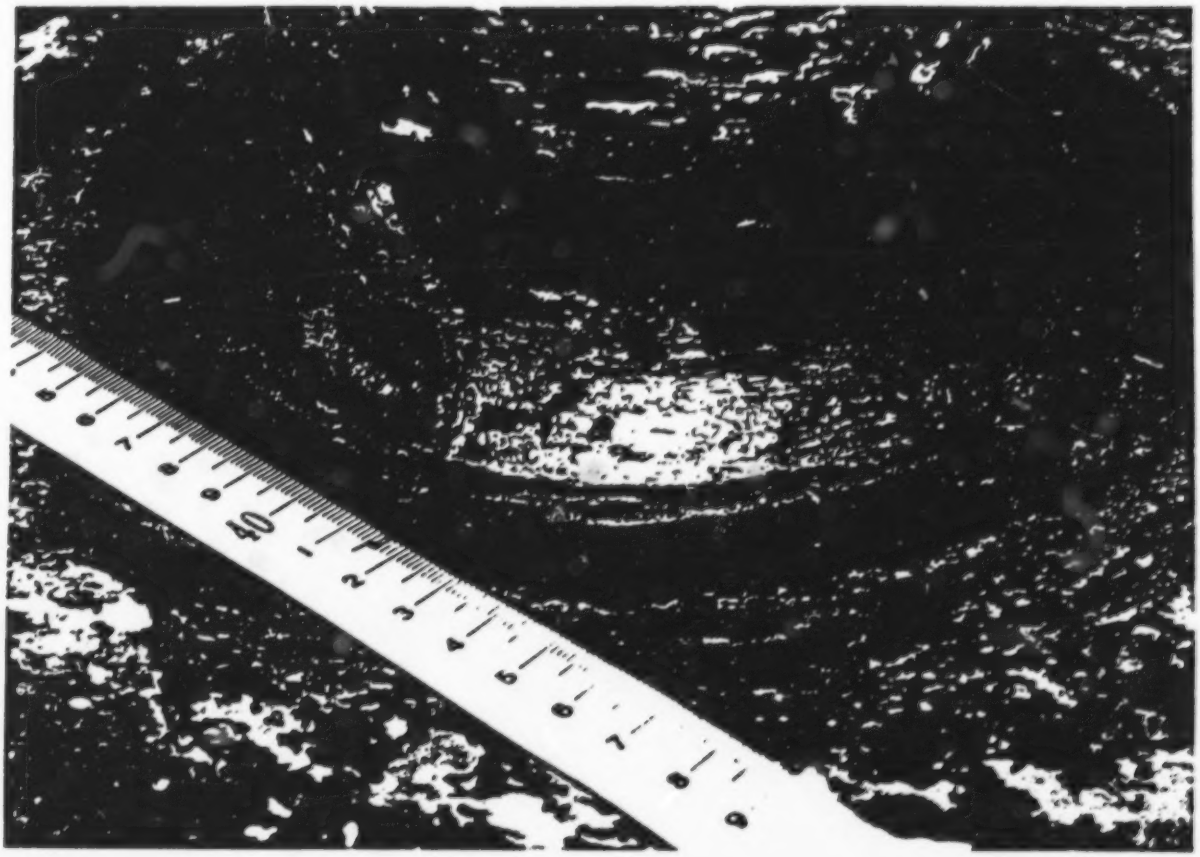


Figure 8: Nozzle casting showing edge penetration

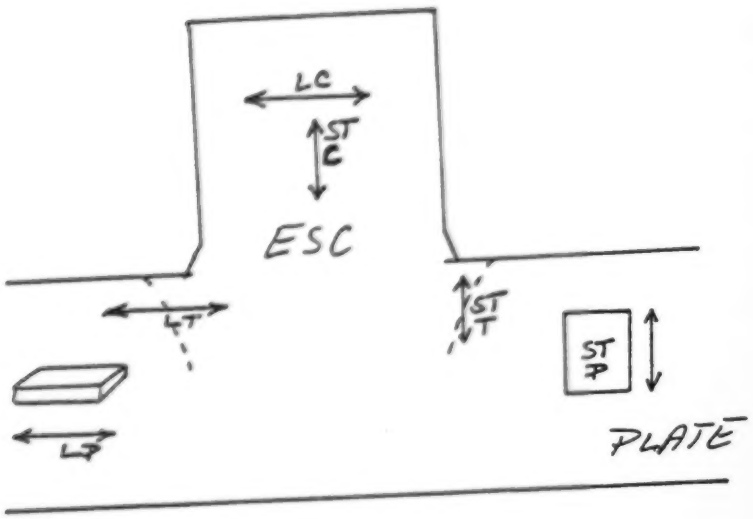


Figure 9: Sample positions for mechanical testing.

POOR

QUALITY

ORIGINAL